Study of the Seismic Recordings Events Close to The Derbendikhan Dam NE–Iraq

Omar Qadir Ahmed[1] and Abdulla Karim Amin*[2]

[1]Department of Geology – College of Science – University of Sulaimani
[2]Department of Social Sciences – College of Basic Education – University of Sulaimani

*Abdullakarim2004@gmail.com

Received: 3 April 2018 Accepted: 4 November 2018

Abstract

In this study the seismic recordings of the recorded events by the installed seismometers in the close proximity to the Derbendikhan dam were analyzed. High resolution data logger instruments were recorded hundreds of earthquakes during February to November 2014. Twenty earthquakes were used for further processing that covered the studied area and surroundings. The analysis of the arrival times and amplitudes of the body waves from different azimuths within optimal range of frequencies from (3 to 750 Hz) had been performed. The waveforms were utilized in determining the various source parameters including location, focal depth and magnitude. Epicentral map was drawn which depicts the epicentral distances of the events from the source. The estimated crustal structure below the studied area reveals that the seismic activities were occurred in the upper part of the crust depths less than (18 km). The magnitude values of the detected earthquakes striking the area were between (2.2 to 5.5). Furthermore, the seismic activities of the study area were possibly associated with the relative movements of the active tectonic plate boundaries as well as due to the increasing and decreasing of the water level of the reservoir. The resulted average values for the P-wave and S-wave velocities were (7.45 km/sec) and (3. 39 km/sec) respectively.

Keywords: Seismic signal, hypocenter, waveform, magnitude, crustal structure, Derbendikhan dam.

دراسة قياسات الزلازل المسجلة بالقرب من سد دربنديخان – شمال شرق العراق

عمر قادرأحمد[1] و عبدالله كريم أمين[2]

[1] قسم علوم الارض – كلية العلوم – جامعة السليمانية

[2] قسم العلوم الاجتماعية – كلية التربية الاساسية – جامعة السليمانية

الخلاصة

تم إجراء تحليل الزلازل المسجلة بجهاز السايزموميتر المثبت بالقرب من سد دربندخان في هذه الدراسة. ولهذا الغرض تم تسجيل المئات من الهزات بدقة من شباط الى تشرين الثاني - سنة 2014. واستخدمت عشرون زلزالا لمزيد من المعالجات و الذي غطى المنطقة المدروسة والمناطق المحيطة بها. ومن خلال تحليل زمن وصول الهزات وسعة الموجات الجسيمية والصادرة من اماكن مختلفة وبتردد (3- 750 هرتز). استخدمت الموجات لتحديد اماكن، عمق و مقدار الهزات. رسمت خريطة لمواقع الهزات وبعدها عن المصدر. اوجدت تركيب القشرة تحت منطقة الدراسة على أن الانشطة الزلزلية حدثت في أعماق أقل من (18 كم) داخل الجزء العلوي من القشرة. اوجدت مقدار الهزات وكانت القيم تتراوح بين (2.2 و 5.5) درجة. علاوة على ذلك قد يعود النشاط الزلزالي لمنطقة الدراسة الى الحركة النسبية للصفائح وارتفاع منسوب الخزان المائي معا. وجدت ان معدل قيم سرعة موجات الأولية والثانوية هي (7.45 كم/ثا) و (3.39 كم/ثا) على التوالي.

الكلمات المفتاحية : الاشارات الزلزالية، جبهة الموج، سعة الموجة، تركيب القشرة، سد دربنديخان.

Introduction

In this study, the process of gathering seismic data had done for converting to identify potential events. The seismic history for this region reveals annual seismic activity at different strength. The northern part of Iraq depicts the highest seismic activity with strong diminution of earthquakes in the southern and southwestern parts of the country [1].

The seismic activity when occurred naturally or induced, the vibrations travel outwards through the ground from the source. Each event radiates seismic waves that travel throughout earth, and several earthquakes per day produce distant ground motions that, although too weak to be felt, are readily detected with modern instruments anywhere on the globe [2]. Initial review of collected data and published bulletins confirms that a large number of small events (magnitude < 4) are either not being recorded or not being detected by distant stations [15].

The territory of Iraq, although not directly located on a dense cluster of recent earthquake epicenters; but the geodynamic configurations show a medium to high seismic risk. This will be coupled with the increasing vulnerability of the major highly populated cities. The state of seismological research, seismic monitoring, and seismic hazard awareness have seen better times during the last two decades, concluded by [12].

Diyala Governorate is one of the most seismically active places in Iraq. Depending on three seismic catalogs (EMSC, IRIS and IRSC), six seismic swarms were distinguished; these are: January 2005, September 2008, June 2009, August 2009, November 2013, and August 2014. Eight focal mechanism solutions were calculated from the GCMT (Global Centroid Moment) catalog. The solutions indicate that the movement on faults in the study area is a reverse movement formed by compressional forces. In order to estimate the directions of the three principal stress axes that effect on faults in Diyala city, [13].

A seismicity study of khanaqin City and surrounding area were concluded that the study area was subjected to four historical earthquakes [14], as follow:

- (128) events occurred within a circular area of radius 50 km around Khanaqin for period 1900 -2012.
- Iraqi Seismological Network (ISN) recorded about 276 events during 22 Nov – 30 Dec /2013.
- Earthquakes were analyzed to find magnitude, focal depth and intensity. The results show, M l = (1.2 –5.6) degree, h = (4 – 27) km, Io = (I – VII) respectively
- Fault plane solutions for study area indicate thrust with some strike slip solutions along planes with NW- SE direction.

Study Area and Seismic Instrumentation

The study area is located at the northeastern part of Iraq at latitude (35° 01^{-} to 35° 13^{-} N) and longitude (45° 39^{-} to 45° 49^{-} E). Which lies within a folded zone to the southwest of the plate boundary, where the Arabian tectonic plate is being subducted beneath the Iranian plate. Derbendikhan Dam is located on the Diyala River, immediately upstream of the town of

Derbendikhan. It is approximately 150 km upstream of the Hemren Dam. The site is approximately 420km by road northeast of Baghdad and 65km southeast of Sulaimaniyah City. It is also within 15km of Iranian border to the southwest [11].

The dam is constructed in a narrow steep-sided gorge, cut through the baranan dagh anticline which was subsequently folded on a series of sedimentary rocks including marls, sandstones, limestone and conglomerate [11]. The upstream shoulder of the dam is founded on the bituminous marl formation. The marly bedding surface is generally weak and its joints are coated with bitumen and weathered residual soil. Downstream of the dam, there is evidence of some cross folding of the QarahChauq limestone.

The Buff formation and bituminous marl foundation make up the dam foundation. The core and downstream shoulder of the dam are founded on the Buff formation [11]. Derbendikhan dam as shown in figure 1 has seismograph station of Triaxial High Frequency installed at the dam site for the monitoring and recording of seismic events.

The seismic monitoring system has its own internal GPS engine that receives an accurate time signal and installed to observe and detect the seismicity over time in three directions as shown in figure 2, which greatly enhanced the triaxial force-based digitization at 24 bit-sps recordings of local and regional seismic activities. This is used to monitor the maximum ground vibration, and record the effects of the earthquakes. Modern seismograms are digitized at regular time intervals and analyzed on computers. Also, seismographs include triaxial geophones were installed in shallow boreholes and powered by solar panels. The seismic station had sited on the concrete base and cemented to the top surface of the dam. Seismic monitoring system, solar panels and GPS antenna were positioned near to the edge of the water reservoir .

Figure 1: Photograph of the Derbendikhan dam

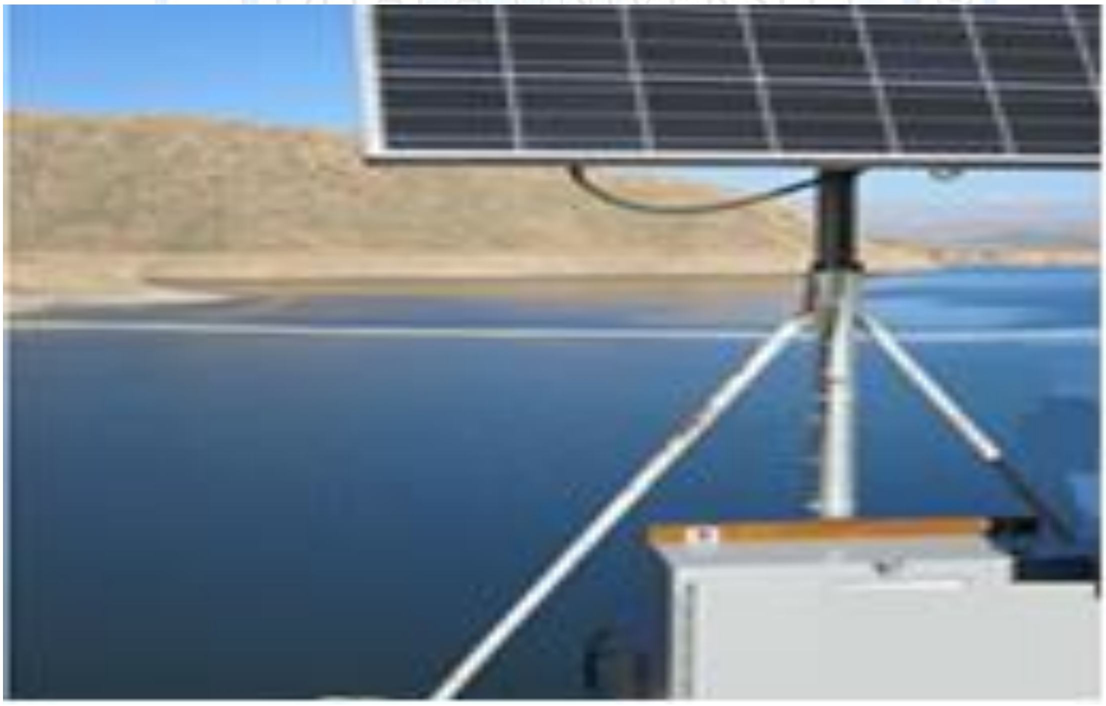

Figure 2: The seismic station at Derbendikhan dam

Data processing

Seismic signals waveforms composed of different frequencies. Continuous analog data were converted into digital data through processing device. More specifically, Analog signals are sampled at a specific sampling frequency. The seismic waves observed in earthquake records show clearly non-stationary characteristics, as well as a wide frequency content [3].

These would be used to gain further information about individual event properties such as source location or other source parameters. In processing technique, the date and arrival-time (h-m-s) for each event is important. If events are triggered on noise rather than legitimate seismic data, it is possible to remove, the processing associated with this event or the events that are deemed noise. Noise may occur at certain frequencies, and are associated with an event, which can be identified and removed from the true data signal by noise frequency filter. The important signal processing operation is to filter the signals to enhance certain features and suppress others [4]. Figure 3 shows unfiltered Seismogram.

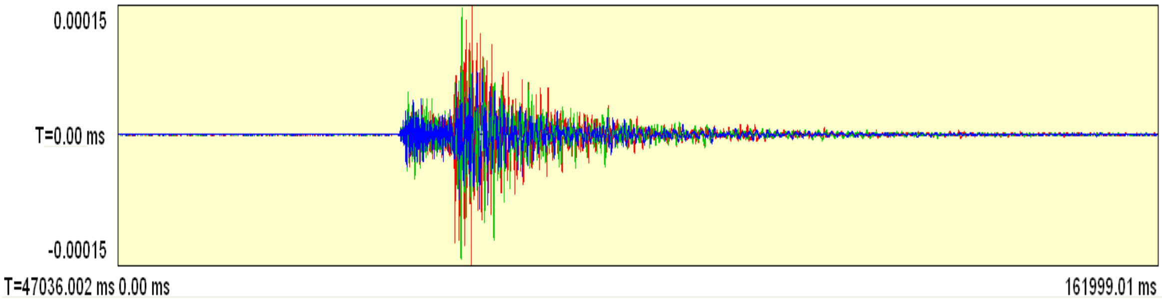

Figure 3: Shows unfiltered Seismogram

The identified detected arrival times of the p-wave and s-waves are processed. The P-wave and S-wave peaks were fixed on the waveform as in figure 4 shown Reveals fixed (P and S) waves after filtering. Filtering is used to improve the quality of the signals by removing noise to obtain optimal Signal / Noise ratio at the time of (P and S) waves peaks.

When the P-wave and S-wave peaks have been adjusted, they were manually processed to obtain the optimal location. From the recorded arrival times on the seismograms, the direct P-waves from various azimuths and the actual distance from the hypocenter were determined.

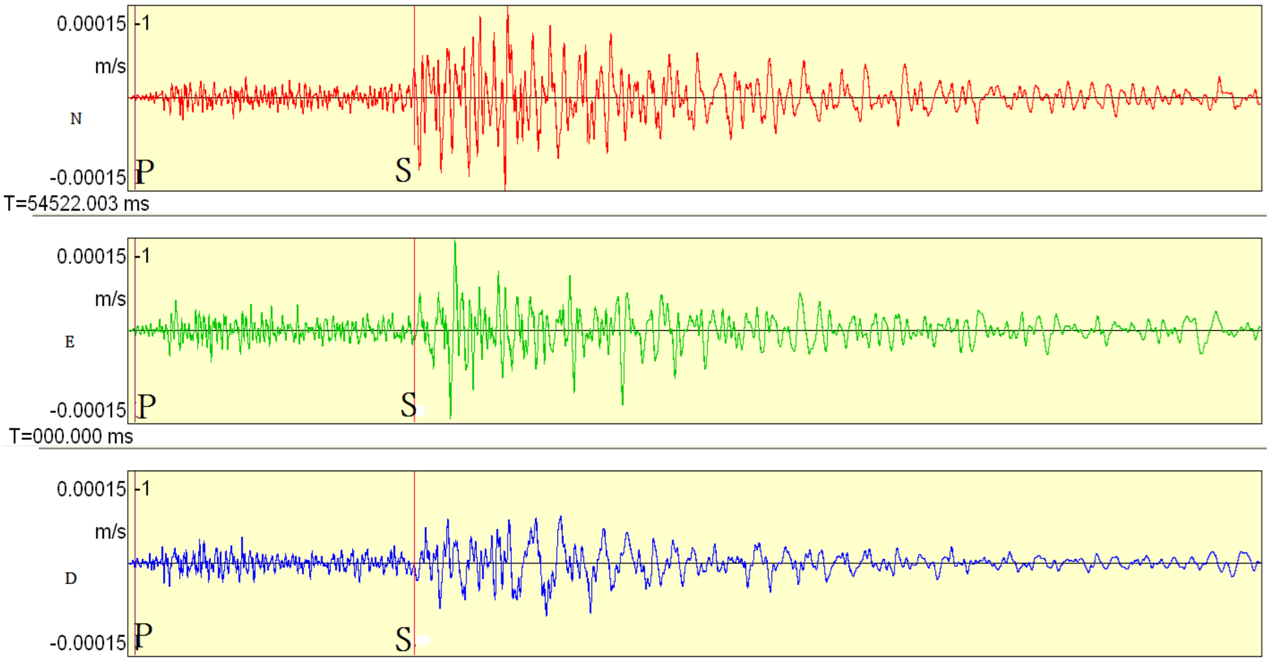

Figure 4: Reveals fixed P- and S- waves after filtering

The event location is numerically approached in an iterative process from an initial trial solution. For each iteration, a correction vector (D_x, D_y, D_z, D_t) was calculated, based on least squares, and added to the previous solution to form a new solution. The iterative approach continues until preset criteria were reached. The solution was derived from the time-distance equation [5].

$$[(x_i-x)^2 +(y_i-y)^2 +(z_i-z)^2]^{1/2} = v(t_i-t)$$

Where x, y, z are coordinates of trial solution, x_i, y_i, z_i location of sensor i, v = velocity, t= event occurrence time, t_i = arrival time at sensor i.

The S-P interval from different stations was estimated. Residual- time calculations had done, in an attempt to minimize the location error and to obtain the best-fit source-location solution. This may be an indication of arrival-time miskicks (which should be less than one).

The residual time is the difference between the theoretical and observed arrival time at a given sensor. The distance between the epicenter and recording station i (epicentral distance) R_i, is obtained by the following equation [6]:

$$R_i = \frac{(t_s - t_p)}{(\frac{1}{v_s} - \frac{1}{v_p})}$$

Where:

$(t_s - t_p) =$ The time difference taken from the earthquake record at the station between the arrival of (P and S) waves, v_P= velocity of P- waves, and v_s= velocity of s-waves.

Fast Fourier transform is a mathematical routine used to convert seismic waveforms from the time domain to the frequency domain. Performing this maintenance on the data will help improve the performance of the arrival time pickers, and thus will obtain more accurate source location and source parameter calculations. It is important to note that events must be source located before source parameter calculations are performed [7].

Determining the magnitude and azimuth of the events is an integral part of processing earthquake data and is done routinely with nearly all earthquakes located, whether global or local. The magnitude of an earthquake is normally estimated by measuring the ground amplitudes record at stations. The general form of empirical equation defining magnitude is [8]:

$$M = \log(A/T) + Q(\Delta, h))$$

Where A is the maximum ground amplitude in micrometers of the wave used, T the wave period in sec, Q is an empirical function of epicentral distance, the distance and h is the focal depth. An example for the azimuth and magnitude determination for the event which occurred in (22 Nov 2014) is shown in figure 5. Information about the frequency content, amplitude of the signals and using the (Hyperion programs ver.14.0) helped in estimating the source location. However, the crustal structure and velocities may differ significantly at various regions, and the event location can be significantly improved when local travel-time curves or crustal models are available. Consequently, the travel time can be used as a function of depth [9].

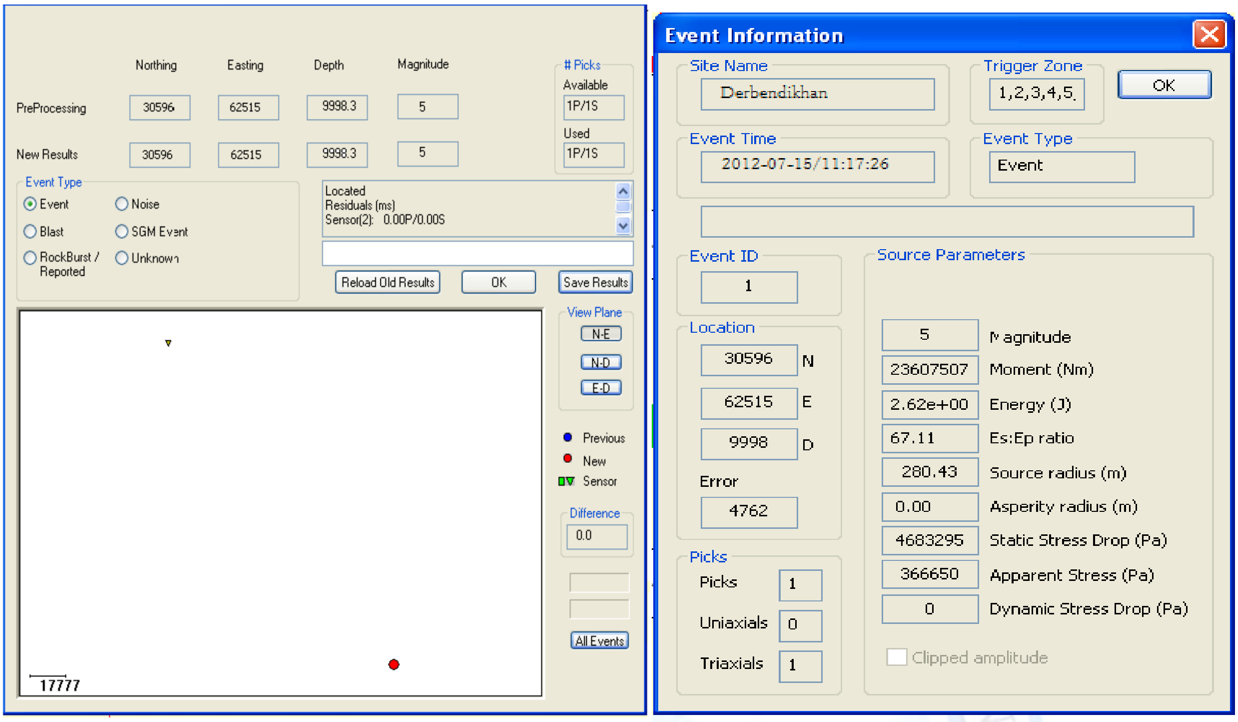

Figure 5: Showing the azimuth and magnitude of the event occurred in 22 Nov.2014

The epicentral map for the selected events had drawn for the studied area and the crustal structure represented by the S-wave velocity versus depth is shown in figure 6, in which the red circles are the processed events occurred in 2014.

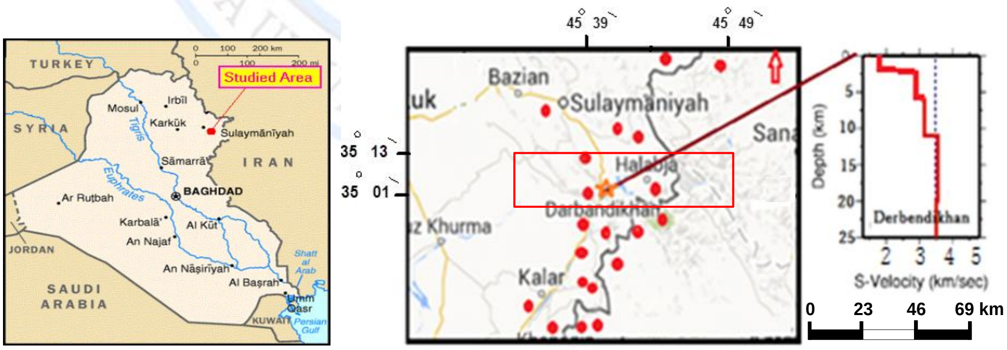

Figure 6: The plotted epicentral map and crustal structure below the studied area

Results and discussion

Statistical analysis between the number of events with their magnitudes occurred during 2014 were performed as shown in figures 7. In principle, statistical analysis could be used for testing a variety of hypotheses, such as the existence of seismic cycles or clustering of main events within the spatio-temporal occurrence [10]. The histogram shown in figure 7a reveals a large number of events increase in the number of occurred recorded earthquakes during 2014. It was observed that the majority of seismic activities were not occurred only during and after the period of very high reservoir levels but before assessing the extra water pressure also. Furthermore, the total recorded event numbers occurred in 2014 was plotted versus magnitude in figure 7b which reveals that most of the events had magnitude values between (1-2).

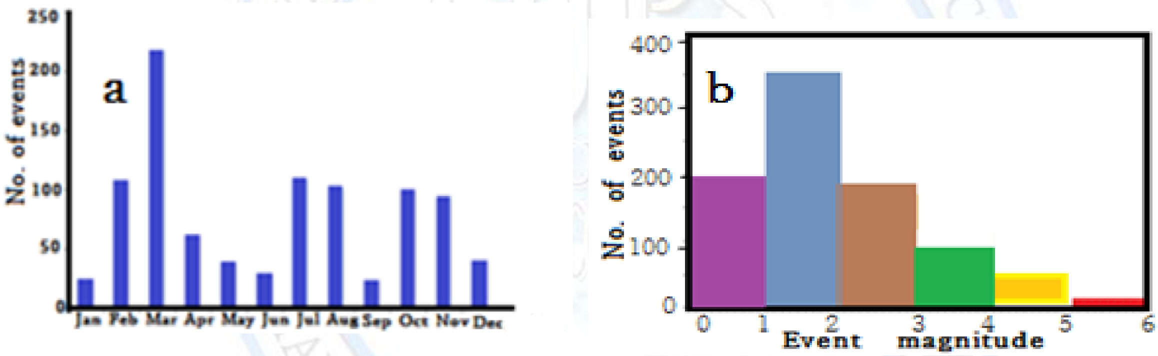

Figure 7: a- Statistical analysis between the numbers of events during 2014. b- Number of events with magnitudes

The total recorded event numbers occurred in 2014 versus magnitude were plotted in Figure 8 which reveals that the magnitude of most of the events were between 1-2. The (P and S) waves velocities were estimated from plotting the hypocentral distances with their interval time values and their values are nearly (7.45 km/sec) and (3.39 km/sec) respectively as shown in the figure 8. The value of the magnitude was varied between (0 to 5.5). The maximum focal depth beneath the studied area is about 20 km, which was supported by A seismicity study of khanaqin City and surrounding area were concluded that the study area was subjected to four historical earthquakes [14], and recorded about 276 events during 22 Nov – 30 Dec / 2013.Earthquakes were analyzed to find magnitude, focal depth and intensity. The results show, Ml = (1.2 –5.6) degree, h = (4 – 27) km, Io = (I – VII) respectively.

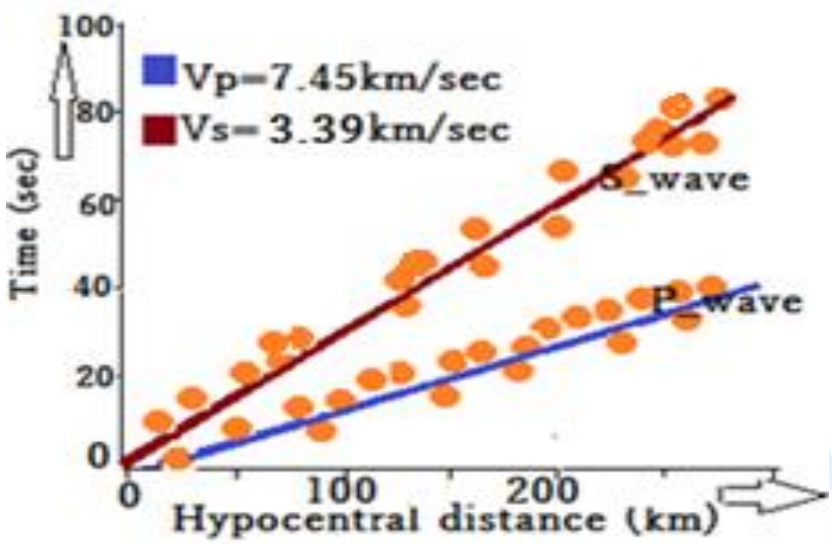

Figure 8: Showing the hypo central distance of the events versus time.

This area was suffered from a large slope failure of the right bank slopes, landslides, leakage and rock falls from the cliffs above the right abutment, as supported by the result of surrounded Diyala city reveals that the movement on faults in the study area is a reverse movement formed by compressional forces. In order to estimate the directions of the three principal stress axes that effect on faults in Diyala Governorate [13], and Fault plane solutions for study area indicate thrust with some strike slip solutions along planes with NW- SE direction [14].

The previous value of (P and S) waves velocities as well the magnitude of seismic wave events were estimated from the source parameters for the selected events occurred in 2014 and recorded by Seismograph are illustrated in table 1.

Table1: Showing the source parameters for the selected events occurred in 2014.

Serial Time	Event Time	Depth (km)	Distance	Azimuth	Magnitude
20:21:18	1/18/2014	1.1	3.8	156.8	3.2
14:22:37	2/1/2014	7.9	71.3	212.5	3.5
7:11:16	2/3/2014	12.6	121.6	90.0	3.9
1:46:48	2/4/2014	17.9	171.9	90.0	4.1
12:03:12	3/23/2014	6.9	78.0	4.2	2.2
17:53:04	3/30/2014	3.9	3.1	185.9	3.1
18:22:54	4/9/2014	14.7	34.2	113.3	2.4
13:22:10	5/3/2014	1.0	54.9	179.9	2.3
4:19:34	6/14/2014	10.3	107.5	175.7	3.5
15:18:06	7/4/2014	9.0	28.5	181.8	3.5
14:09:14	7/10/2014	20.0	471.6	158.4	4.0
11:17:26	7/15/2014	9.9	73.5	325.8	5.0
16:56:18	8/13/2014	3.1	62.8	231.7	3.6
7:42:17	8/25/2014	15.6	15.8	268.8	4.1
5:52:05	9/6/2014	3.5	5.0	327.1	2.5
10:29:32	9/30/2014	12.1	15.1	268.9	2.5
8:15:35	10/7/2014	11.9	35.9	340.8	4.4
9:25:51	10/9/2014	7.7	68.0	239.9	4.4
11:33:16	11/10/2014	4.1	3.1	114.8	3.1
11:13:43	12/4/2014	7.8	10.5	330.8	4.0

The results were indicated that the depth of the recorded events was range between (1.1 to 20 Km), which appear natural seismic activities in the Dam site and surrounding area were related to narrow and great depth within the Earth crust. Whereas the events magnitude range between small magnitude (2.2) to intermediate magnitude (5) values seismic activities during year 2014. But it may increase from this range due to the source that locates in highly active seismicity area in border area between Iraq and Iran (Zagrose mountain series), if the detection of any large magnitude earthquake could represent a threat to dam safety.

Conclusions

In this study it can be concluded that there is a clear variation in magnitude values which reveal changes in the seismicity of the studied area. The detected large magnitude earthquakes were possibly associated with relative movements of the Eurasian and Arabian tectonic plates while the small events (magnitude < 3) might be due to the sudden raising and lowering of the water level in the reservoir. Accordingly, tectonic movements and the extra water pressure were resulted these vibrations. And, this area was suffered from a large slope failure of the right bank slopes, landslides, leakage and rock falls from the cliffs above the right abutment. Because the upstream shoulder of the dam is founded on a weak marl formation, the detection of any large magnitude earthquake could represent a threat to dam safety. Furthermore, the focal depth values indicate that all the recorded events in the study area were shallow earthquakes (less than 20 km) and occurred within the upper crust or lithosphere.

Acknowledgements

We would like to acknowledge the staff of Derbendikhan dam directorate, which their assistance was facilitated the development of this study.

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